

PALESTINE.



DEPARTMENT OF DEVELOPMENT.

# REPORT

ON DUTY OF WATER INVESTIGATIONS  
ON CITRUS CULTIVATION

AT

GAN MOSHE, NEAR RISHON LE TSIYON

DURING THE YEARS

1931-32-33

BY

J. DAWSON SHEPHERD, O.B.E., C.D.A.

M. J. GOLDSCHMIDT, DIPL. ING.

J. D. OPPENHEIM.

Price 50 Mils.

To be purchased directly from the  
PRINTING & STATIONERY OFFICE, JERUSALEM.







PALESTINE.



DEPARTMENT OF DEVELOPMENT.

# REPORT

ON DUTY OF WATER INVESTIGATIONS  
ON CITRUS CULTIVATION

AT

GAN MOSHE, NEAR RISHON LE TSIYON

DURING THE YEARS

1931-32-33

BY

J. DAWSON SHEPHERD, O.B.E., C.D.A.

M. J. GOLDSCHMIDT, DIPL. ING.

J. D. OPPENHEIM.

Price 50 Mils.

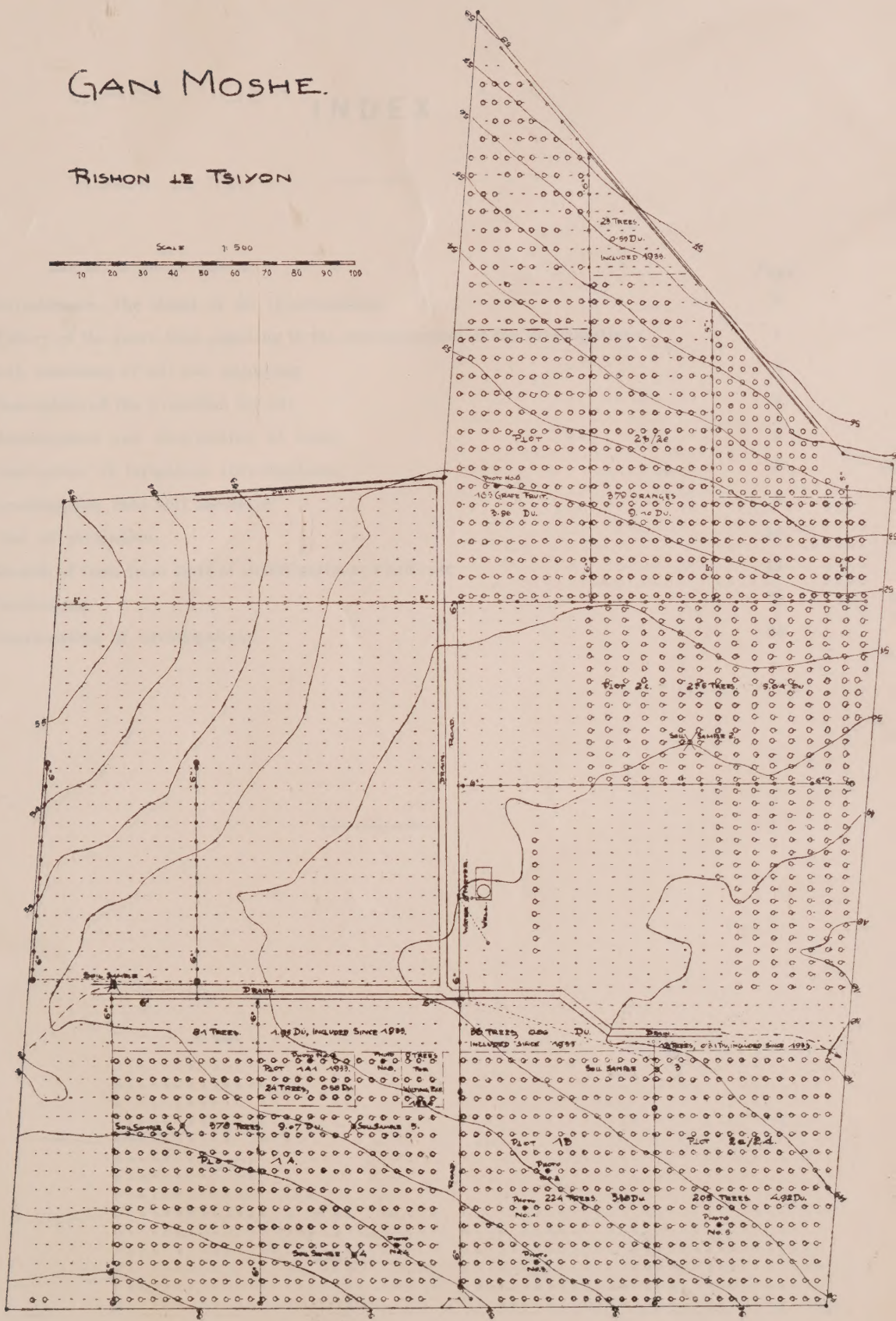
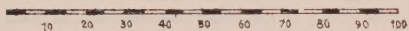
To be purchased directly from the  
PRINTING & STATIONERY OFFICE, JERUSALEM.





RISHON LE TSIVON

Scale 1: 500



SHOON LAD

MARKET 2. HONOR

1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15. 16. 17. 18. 19. 20. 21. 22. 23. 24. 25. 26. 27. 28. 29. 30. 31. 32. 33. 34. 35. 36. 37. 38. 39. 40. 41. 42. 43. 44. 45. 46. 47. 48. 49. 50. 51. 52. 53. 54. 55. 56. 57. 58. 59. 60. 61. 62. 63. 64. 65. 66. 67. 68. 69. 70. 71. 72. 73. 74. 75. 76. 77. 78. 79. 80. 81. 82. 83. 84. 85. 86. 87. 88. 89. 90. 91. 92. 93. 94. 95. 96. 97. 98. 99. 100.



## INDEX

---

|                                                                                    | <i>Page</i> |
|------------------------------------------------------------------------------------|-------------|
| 1. <i>Introduction</i> , The object of the investigations. - - - - -               | 1           |
| 2. History of the grove from planting to the commencement of the investigations. - | 1           |
| 3. Soil, treatment of soil and manuring. - - - - -                                 | 2           |
| 4. Description of the irrigation lay-out. - - - - -                                | 4           |
| 5. Measurement and distribution of water. - - - - -                                | 5           |
| 6. Description of irrigation investigations. - - - - -                             | 5           |
| 7. Investigation into soil moisture. - - - - -                                     | 8           |
| 8. Cost of irrigation. - - - - -                                                   | 14          |
| 9. Growth of trees from start of investigations; yield; etc. - - - - -             | 17          |
| 10. Conclusions. - - - - -                                                         | 23          |
| 11. Continuation of investigations. - - - - -                                      | 24          |

---





# DUTY OF WATER INVESTIGATIONS ON CITRUS CULTIVATION IN THE GAN-MOSHE GROVE NEAR RISHON-LE-TSIYON.

## 1. INTRODUCTION AND OBJECT OF INVESTIGATION.

A series of investigations in connection with irrigation practice and duty of water has been carried out on a field scale since 1931 in the Gan Moshe Grove, near Rishon Le Tsiyon, managed by Messrs. A. J. Polak and J. D. Oppenheim, Plant Physiologist. There is considerable controversy regarding this most important branch of citrus culture in Palestine and figures obtainable from available literature are indefinite and differ very considerably. From previous records it would appear that the quantities of water used and the methods of irrigation employed have been based on established practice and local procedure. (See Table I in Appendix).

The objects of the investigations which are being continued and extended, are to ascertain the optimum duty of water in this grove, the most desirable method of irrigation in its cultural and economical aspect and generally to provide data which will enable cultivators in areas with varying soil conditions and plantation lay-outs to apply the methods employed to their own groves.

The Gan Moshe grove is one suited to investigation work on a field scale. It contains soils of different representative qualities and is managed in accordance with modern and scientific principles. Many thanks are due to the Managers of the grove for their cooperation in the investigations and for their willingness to carry them out; to Mr. Blumenkranz, the foreman of the grove who carried out the details of the investigation work with great care and to Dr. (Miss) De Beer who carried out soil moisture and physiological investigations.

## 2. HISTORY OF THE GROVE FROM PLANTING TO THE COMMENCEMENT OF THE INVESTIGATION.

The total area is 83.4 dunums. Planting was done in the spring of 1930. The soil was deep ploughed to 80—90 cm in the preceding summer and following careful cultivation of the surface layers of the soil the trees were planted out 4 by 6 meters apart. The reasons for choosing this distance are as follows. The older groves in Palestine are very densely planted and bear fruit mainly in the top of the trees. The soil and the tree trunks are in continual shadow and this, coupled with over irrigation, is conducive to disease and a shortening of the life of the tree. The younger groves with wider spacing  $4 \times 4$ ,  $4.5 \times 4.5$  show improvement in health but this spacing does not permit the proper care of the tree and the handling of the fruit. It is to be expected that mechanical labour will increasingly displace hand labour and, to permit this, wider spacing than the above is required. Large groves are being planted out at  $5 \times 5$  metres, i. e. 25 square metres per tree but after eight years it is found difficult if not impossible to work with tractors or horses in such groves. Spacing  $6 \times 6$ ,  $6 \times 7$ ,  $7 \times 7$ , was judged too large and wasteful, so  $4 \times 6$  was chosen and expected to permit mechanical work for a fairly long period in the 6 meter rows. It will be recognised of course that cultivation and irrigation take place in the six meter wide row.

H. Clark Powell writes on page 283 of his book *"The Culture of the Orange and Allied Fruit"* :

"One of the most striking points about the groves in Palestine is the very short distance between the trees. In the older plantings, and in some of the recent ones, the trees are set 3 to 4 meters apart (10 to 13 feet) and a few groves exist with the trees only 2 meters apart.

"The result of such planting is that the closely planted groves are simply a thicket of trees in which it is frequently impossible to walk erect. While the production per acre of such groves is very high, the production per tree is very low, normally less than an average of one case of fruit. Costs of production per acre are high, as nothing but hand labour can be utilised because the trees are so close together. Because of the high yield of fruit per acre, due to the large number of trees per acre, the cost of production per case is low.

"Although the production of fruit per acre is higher than in any other country of the world, averaging about 400 cases, it could be raised by increase in the planting distance to 5 — 6 metres. When trees are planted  $3\frac{1}{2}$  by  $3\frac{1}{2}$  metres (11 feet by 11 feet) there will be 360 trees per acre. When trees are planted at  $5\frac{1}{2}$  by  $5\frac{1}{2}$  metres (18 by 18 feet) there will



“be 134 trees per acre. A yield of 4 cases per tree can readily be obtained with this latter planting distance and such a yield would give 536 cases per acre, an increase of 176 cases over the closely planted trees, if the latter averaged one case of fruit per tree. Even with an average yield of 3 cases per tree with the trees planted at  $5\frac{1}{2}$  metres, the increase would be marked.

“The writer noted one particular case in Palestine in 1927 where a marked increase in yield resulted from increasing the planting distance in a bearing grove. The trees were originally planted at  $3\frac{1}{2}$  metres apart and a sufficient number were removed to leave the balance at 5 metres apart. In four years production increased from an average of one case per tree to five cases per tree and the grower expected to raise the average still more. The increase in production from one case to five cases meant an increase from 360 to 670 cases per acre.”

The trees planted were as follows :—

|             |          |                        |
|-------------|----------|------------------------|
| 23.2 dunums | Shamouti | grafted on Sweet Lime. |
| 10          | “        | “ “ Sour Stock.        |
| 12          | “        | Grape Fruit “ “ “ “    |

These areas are net metric dunums.

The remaining area was planted with Sweet Lime and Sour Stock which were grafted in the Autumn of the same year.

The grafted trees were planted in holes 80 cm. × 80 cm. and 60 cm. deep. The holes were opened about ten days before planting and the trees were planted with balls of earth. Special care was taken to have the balls as long as possible in order to make use of the main root, since experience has shown that regeneration of the younger part of the main root is much better than the older. A half kilogram of finely ground bone meal was mixed with the soil in the hole.

The treatment of the grafted orange trees before planting differed. 200 trees were pruned in the common Palestine method i. e. main branches were cut back to 20—25 cm. from the stem. The other trees were not pruned. The results were very striking. It was nearly two months before the pruned trees showed any new sprouts and they did not recover the loss from pruning during the first year. The unpruned trees started new growth within two weeks after planting and at the end of the season were in remarkably good condition. There was indeed little difference to be noticed between these transplanted trees and trees left in the ground. The pruned trees did not recover properly until after the second season and it may be concluded that, by this pruning, development was delayed for a full year. On the other hand, the grape fruit were pruned before planting to about 40 cm. from the stem and recovered the loss in about three months.

The stocks were planted without balls and were cut back to about 60 cm. above the soil. The side roots were pruned but the stem was not entirely defoliated and remained after planting with 5 to 6 leaves. The plants were packed closely in tins, well covered with wet sacks, after the roots had been dipped in a sludge of loamy sand. They were transported to the planting site a distance of about 10 kilometers. The plants started to form new roots about two weeks after planting and sprouted six weeks after planting. Two months after, they were entirely clothed with new shoots and 95% of them were budded in the autumn.

The young buds started to sprout about the second half of March 1931. The stocks were broken about 40 cm. above the bud in the beginning of April but were not cut down to the bud until root formation started towards the beginning of June. When about 1.10 metres above the ground, the buds were cut back some 35 cm.

All the shoots that developed after this pruning remained on the tree but no more than two shoots were permitted from one place. During the further development, the trees were not pruned and were shaped by training.

It is emphasised that too much care cannot be taken in the planting and the early treatment of the tree. The success of a grove is largely dependent upon it.

### 3. SOIL, TREATMENT OF SOIL AND MANURING.

Mechanical and chemical soil analysis were made and the irrigation water was also analysed.

An analytical report is attached. (Appendix No. III).

The hydrogen ions concentration (showing the reaction) was also determined and found to vary between 7.6 and 7.9 pH (light alkaline reaction) which is characteristic of soil suitable for citrus culture.



From the mechanical analysis it will be seen that the soils are light and that the lightness decreases with the depth. The heavier soil may be termed a typical loamy, sandy soil. The light sandy soil shows good physical properties but the chemical properties are bad owing to a deficiency in calcium, phosphates, potash and total nitrogen. The humus content is also very low.

On different occasions the opinion has been expressed by experts that the main manure required in Palestine is, based on Californian experience — nitrogen. In view of the analysis of the Gan Moshe soil which is fairly typical of Palestine citrus soils, the necessity for other manures than nitrogen would appear evident and investigation in connection with this question is emphasised. The necessity for a bulky organic manure in view of the low humus content also calls for study.

In 1930 the grove was ploughed with the Arab plough three times in summer. It was manured as follows :—

TABLE 1.

|                           | Date |          |                    |
|---------------------------|------|----------|--------------------|
| Grape-fruits              | 15/3 | 150 gram | Nitrochalk p. tree |
| Grafted                   | 15/7 | 200 "    | Superphosphate "   |
|                           | "    | 200 "    | "Patent-Kali" "    |
| Shamouti on               | 15/3 | 200 "    | Nitrochalk " "     |
| Sour Stock                | 15/7 | 175 "    | Superphosphate "   |
| Grafted.                  | "    | 250 "    | "Patent-Kali" "    |
| Shamouti on               | 15/7 | 250 "    | Sulph. Ammoniak "  |
| Sweet lime                | "    | 175 "    | Superphosphate "   |
| Grafted                   | "    | 275 "    | "Patent-Kali" "    |
| Shamouti on               | 15/3 | 75 "     | Sulph. Ammoniak "  |
| Sweet lime.               | 15/7 | 75 "     | Nitrochalk " "     |
| Grafted after<br>planting |      |          |                    |

In 1931 the grove was ploughed with the Arab plough eight times and manured as per table 2.

TABLE 2.

|                            |      |            |                           |
|----------------------------|------|------------|---------------------------|
| Grape fruits.              | 15/3 | 350 gram   | Nitrochalk p. tree        |
| Grafted                    | 15/7 | 300 "      | Superphosphate "          |
|                            | "    | 500 "      | "Patent-Kali" "           |
|                            | 1/10 | 15 kg.     | Organic manure "          |
| Shamouti on                | 15/3 | 300 gram   | Nitrochalk " "            |
| Sour stock.                | 15/7 | 300 "      | Superphosphate "          |
| Grafted.                   | "    | 500 "      | "Patent-Kali" "           |
|                            | 1/10 | 15 kg.     | Organic manure "          |
| Shamouti on                | 15/3 | 350 gram   | Nitrochalk " "            |
| Sweet lime.                | 15/7 | 400 "      | Superphosphate "          |
| Grafted.                   | "    | 500 "      | "Patent-Kali" "           |
|                            | 1/10 | 15 kg.     | Organic manure "          |
| Shamout on                 | 15/7 | 150 gram   | Superphosphate "          |
| Sweet lime                 | "    | 150 "      | "Patent-Kali" "           |
| Grafted after<br>planting. | 1/10 | 7½ kg.     | Organic manure "          |
|                            | 15/2 | Heavy soil | 100 kg. per dunum } Lime. |
|                            | "    | Light soil | 50 kg. " " }              |

In 1932 the grove was ploughed nine times and manured as per table 3.

TABLE 3.

|                            |      |          |                      |
|----------------------------|------|----------|----------------------|
| Grape fruits               | 15/3 | 500 gram | Sul. Ammoniak p.tree |
| Grafted.                   | "    | 150 "    | Superphosphate "     |
|                            | 1/10 | 20 kg.   | Organic manure "     |
| Shamouti on                | 15/3 | 400 gram | Sulph. Ammoniak "    |
| Sour stock                 | "    | 200 "    | Superphosphate "     |
| Grafted.                   | 1/10 | 20 kg.   | Organic manure "     |
| Shamouti on                | 15/3 | 500 gram | Sulph. Ammoniak "    |
| sweet lime                 | "    | 250 "    | Superphosphate "     |
| Grafted.                   | 1/10 | 20 kg.   | Organic manure "     |
| Shamouti on                | 15/3 | 300 gram | Sulph. Ammoniak "    |
| Sweet lime.                | "    | 150 "    | Superphosphate "     |
| Grafted after<br>planting. | 1/10 | 10 kg.   | Organic manure "     |

In 1933 the grove was ploughed nine times and manured as per table 4.

TABLE 4.

|              | Date |            |                          |
|--------------|------|------------|--------------------------|
| Grape fruits | 15/2 | 1000 gram  | Sul. Ammoniak p.tree     |
| Grafted.     | "    | 500 "      | Superphosphate "         |
|              | 1/7  | 1000 "     | Sulph. Ammoniak "        |
|              | "    | 500 "      | Superphosphate "         |
|              | "    | 1000 "     | "Patent-Kali" "          |
|              | 1/10 | 50 kg.     | Organic manure "         |
| Shamouti on  | 15/2 | 750 gram   | Sulph. Ammoniak "        |
| Sour stock   | "    | 400 "      | Superphosphate "         |
| Grafted.     | 1/7  | 750 "      | Sulph. Ammoniak "        |
|              | "    | 400 "      | Superphosphate "         |
|              | "    | 600 "      | "Patent-Kali" "          |
|              | 1/10 | 40 kg.     | Organic manure "         |
| Shamouti on  | 15/2 | 400 gram   | Sulph. Ammoniak "        |
| Sour stock   | 15/7 | 150 "      | Superphosphate "         |
| Grafted.     | 1/7  | 250 "      | Sulph. Ammoniak "        |
|              | "    | 250 "      | Superphosphate "         |
|              | "    | 400 "      | "Patent-Kali" "          |
|              | 1/10 | 40 kg.     | Organic manure "         |
|              | 15/2 | Heavy soil | 100 kg. per dunum }      |
|              | "    | Light soil | 50 kg. per dunum } Lime. |

In addition to the supply of the above manures, green manure was ploughed in during 1931 and 1932. For the light soil lupins were grown and, for the heavy soil, horse beans.

#### 4. DESCRIPTION OF THE IRRIGATION LAY-OUT.

The grove is divided into two main blocks by the main road, running parallel to the Eastern boundary, which is more or less equi-distant from the Eastern and Western boundary.

The pumping plant is situated on this road near the centre of the square portion of the grove. It consists of a constructed shaft well 32.10 metres deep and 3.50 diameter. This was carried almost to the underground water table which was tapped at about 32.30 metres depth. From the base of the shaft a bore was drilled 12" in diameter which reached rock at 56.0 metres below the base of the shaft and penetrated the rock to a further depth of 1.8 metres. The rock was so penetrated in order to obviate the necessity for the installation of a filter which has but a limited life.

A centrifugal pump to deliver 75 metres cube per hour to an average head of 45 metres, driven by a 20 H.P. electric motor was installed at the base of the well. The pump delivers through a 6" pipe. A 5" Woltmann water meter was inserted in this pipe outside the well house in 1931 before the investigations were started.

The delivery pipe has a bifurcation behind the Woltmann meter. One branch runs south and the other north along the main road. These pipes branch into secondary and tertiary pipes, at right angles and parallel to the main road in order to enable economic irrigation of the whole area at such slopes as would prevent soil erosion during watering.

All pipes were buried 60 cm. below the ground surface, and were laid at such distances apart that at no place does the length of the water stream from them exceed 70 metres. Where the slope was fairly steep this length was reduced to 40 metres, in order to lessen the quantity of water in each stream and thus prevent erosion. Due to these precautions, taken in designing the lay-out, there has been no erosion since irrigation started.

The main 6" pipe and the secondary and tertiary pipes of 5" where the inside hydraulic pressure is more than 3 m. head, are of steel. Secondary and tertiary pipes of 6" which had to stand an hydraulic pressure of more than 3 m. head are made of spun reinforced concrete; all pipes to withstand less pressure than the above are 6" diameter and made of plain concrete.

Sluice valves were installed at the most important bifurcations in order to enable complete control over distribution.

The irrigation pipes carry "Irrigation Fittings" oposite each row of trees, at 6 metres apart. Each fitting consists of a raiser connected to the pipe. This carries at its end a "Californian Irrigation Valve" discharging into a circular concrete box of 30 cm. diameter and 60 cm. height which surrounds it. The top of the raiser is flush with the cement floor of the box. The irrigation box has 4 openings 20 cm. below the top, provided with 2" galvanized iron slide gates. These outlets are almost flush with the ground surface.



## 5. MEASUREMENT AND DISTRIBUTION OF WATER.

During the irrigation of any investigation plot the total quantity delivered by the pump is measured through the Woltmann meter and conducted to the plot. The meter was checked in the spring of 1933 by means of a Poncelet weir and found to be correct.

The problem of equal distribution of the total delivery to the plot through a large number of irrigation fittings, working simultaneously, is dealt with as follows: The irrigation box is a form of measuring box with its four 2" slide gates. The centre of each outlet is 20 cm. below the top of the box and the quantity of water discharged from each when the slide door is open full depends upon the head of the water surface in the box above the centre of the outlet. The formula is :—

$$Q = \mu h \left[ 1 - \frac{1}{32} \left( \frac{r}{h} \right)^2 - \frac{1}{1025} \left( \frac{r}{h} \right)^4 - \dots \right] \pi r^2 \sqrt{2gh}$$

$\mu$  = contraction coefficient.

$h$  = head above centre of outlet.

$r$  = radius of outlet.

$g$  = gravity coefficient.

(See Forchheimer, *Hydraulik* 2nd edition p. 255).

All measures in technical units.

It is possible to discharge from a certain number of entirely open 2" outlets approximately equal quantities of water if the water surface in all the boxes be kept at equal head above the centre of the outlets. After a reasonably short time the workman in charge of the irrigation gained enough experience to keep the water in working distribution boxes at a sufficiently equal head so that each of the outlets —  $N$  in number — discharged as nearly as is possible  $\frac{1}{N}$  of the whole delivery of the pump. More meticulous measurement under field conditions does not appear possible.

In this connection it may be mentioned that the number of fittings working at one time was increased in 1933 to 14 in furrow irrigation; having previously been 8 in 1931 and 12 in 1932. The total number of streams was therefore  $14 \times 4 = 56$ . The total discharge of the pump was about 75 metres cube per hour. This quantity, divided by the fittings into 56 approximately equal streams was controlled by a single workman. This was rendered possible by the division of the quantity into such a large number of small streams which do not call for close supervision. In basin irrigation the total discharge of the pump was divided into 5 or 6 equal streams each being fed from one irrigation fitting. One workman was required for each stream. The economy of furrow irrigation during watering will be recognised. For further details see section 8, Cost of Irrigation.

The equal distribution of the water throughout the whole plot was obtained as nearly as possible in the following manner :—

(a) *Furrow Irrigation.* Water ran through the whole length of the furrow in a comparatively short time (not more than 15 minutes). The stream continued through the whole length of the furrow during several hours. Towards the end of the period small checks were made in the furrow, commencing from the end of it furthest from the fitting and the basins thus formed filled up in succession from the end to about the fourth tree from the intake. Moisture investigations in 1933 appear to give proof that the water was fairly evenly distributed over the whole length of the furrow. For details see section 7, Moisture Investigations.

(b) *Basin Irrigation.* The basins at each tree were equally sized and filled with water to the same depth.

## 6. DESCRIPTION OF IRRIGATION INVESTIGATIONS.

In the spring of 1931 various small plots in the grove containing soil representative of the whole grove were chosen for investigation. The plots are shown on the attached plan of the grove. The areas given are net and are calculated on the basis of the number of the trees each covering 24 sq. metres. For details of Irrigations see Table II in the Appendix.

### INVESTIGATION No. 1.

Furrow irrigation was followed with two different water allowances. Two plots were chosen in the northern section of the grove with normal sandy soil. Plot A. East of the main road containing 378 trees over 9.07 dunums. Plot B, West of the main road, 224 trees over 5.38 dunums. The trees were all Shamouti planted out grafted on sweet lime stock.

During the irrigation season 1931, Plot A received on the average every 44 days between 75.8 m<sup>3</sup> and 98.0 m<sup>3</sup> per dunum. Plot B received on the average every 40 days between 73.1 m<sup>3</sup> and 106.3 m<sup>3</sup> per dunum. Each plot received 3 irrigations only during the irrigation season.

The total quantity supplied was :—

Plot A 260.7 m<sup>3</sup> per dunum or 6.27 m<sup>3</sup> per tree.

Plot B 268.5 m<sup>3</sup> per dunum or 6.45 m<sup>3</sup> per tree

The difference between the actual quantities of water supplied to the different plots in 1931 is small but it must be recognised that this was a period during which experience was being gained in distribution.

The distribution on each plot was through two furrows from each irrigation fitting. The furrows were between a metre and a metre and a half from the trees and passed on either side of them.

In 1932, since root development had made much progress, the water was distributed through four furrows equidistant from each other in the six metre rows.

Plot A received every 45 days between 100 m<sup>3</sup> and 111.3 m<sup>3</sup> per dunum and plot B every 35 days between 95.6 m<sup>3</sup> and 100 m<sup>3</sup> per dunum. Plot A received 3 and Plot B 4 waterings in the season. Total quantities of water were as follows:—

Plot A 313.3 m<sup>3</sup> per dunum or 7.53 per tree.

Plot B 390.2 m<sup>3</sup> per dunum or 9.38 per tree.

In winter 1932/33 the area of which plot A and B is a part yielded fruit as recorded in section 9 of this report. In 1933, the areas under investigation were slightly altered. In Plot A an area of 0.576 dunums, (24 trees) was isolated and this area called Plot A1. It received in September about  $\frac{3}{4}$  of the quantity of water supplied per dunum to the rest of the area. This was done in order to reduce further the minimum supply. In order to meet the arrangements of the Manager, 81 trees budded after planting in 1930, irrigated from the same pipe but, in previous years, not at the same time, as the remainder of plot A, were irrigated with plot A which was thus increased by 1.944 dunums. The total area of the plot A thus became 10.44 dunums. Similarly plot B was increased by 36 trees and its area thus became 6.24 dunums.

The water was equally distributed on the increased area but, for investigation purposes, only trees under experiment since 1930 are considered.

Plot A received about every 44 days from 131.8 m<sup>3</sup> to 109.3 m<sup>3</sup>. Plot A1 received the same at the first two irrigations but only 76.5 m<sup>3</sup> per dunum at the last irrigation. Plot B received about every 36 days from 134 to 100.2 m<sup>3</sup> per dunum. Plot A and A1 received three irrigations. Plot B four. The following shows total quantities of water:—

Plot A. 360.9 m<sup>3</sup> per dunum or 8.67 m<sup>3</sup> per tree.

Plot A1. 328.1 m<sup>3</sup> per dunum or 7.87 m<sup>3</sup> per tree.

Plot B. 443.8 m<sup>3</sup> per dunum or 10.67 m<sup>3</sup> per tree.

In the late Autumn of 1933 one exceptional irrigation was given in view of the lack of rain. The quantity of this irrigation is not however included in the above figures. It should be noted that it was necessary in order to complete the irrigation of the plot to give in the first irrigation of the season a quantity of water in excess of the estimate which was in the neighbourhood of 100 m<sup>3</sup> per dunum. Similarly in the general practice experiment the first irrigation required more water than the following irrigation. The quantity required for the general practice on light soil (plot 2d) for the first irrigation was much the same as that on plots 1A and 1B. The feature is discussed in Section 7.

INVESTIGATION No. 2a and 2d.

This may be regarded as a record of what may be called general practice in this grove on light soil. In other words the foreman of the grove irrigated the trees in accordance with his conception of requirement while taking measurements of the quantity of water supplied. The plot is in the Northern part of the grove West of the main road, near the main drain, at the Western boundary. The soil is the same as that in plots 1A and 1B. The number of trees in the plot in 1931 was 205 covering an area of 4.92 dunums. The trees were planted out already grafted Shamouti on sweet lime.

In 1931—32 the basin irrigation system as described in section 5 was used.

In 1931 the average interval between irrigations was 42.3 days and the quantity of water used in one irrigation varied from 37.6 to 79.3 m<sup>3</sup>/d. The number of irrigations was four and the total quantity of water during the season per dunum was 251.6 m<sup>3</sup> equal to 6.05 m<sup>3</sup> per tree which is slightly less than that used in plot 1A.

In 1932 the average interval between irrigations was 32 days. The quantity of water used in one irrigation varied from 80 m<sup>3</sup> to 120.8 m<sup>3</sup> per dunum. The number of irrigations was five; the total quantity supplied per season per dunum was 493.3 m<sup>3</sup> equal to 11.86 m<sup>3</sup> per tree. This is much more than used for Investigation No. 1A: (313 m<sup>3</sup> per dunum or 7.53 m<sup>3</sup> per tree) and even more than used for Investigation 1B (390.2 m<sup>3</sup> per dunum or 9.38 m<sup>3</sup> per tree). This plot bore fruit in 1932.

In 1933 the basin irrigation system was dropped in this plot. The economic advantages of the furrow system having been demonstrated in plots 1A and 1B, it was now employed, 4 furrows in each row being used. The investigation was now called 2d. The area was increased



to 5.23 dunums and the number of trees to 218 by the inclusion of 13 trees on the main drain which had been budded in situ in the autumn of 1931. These were now irrigated with the 205 trees of the first two years.

The average interval between two irrigations was 35.7 days; quantity of water per irrigation varied from 90.1 to 128.5 m<sup>3</sup> per dunum, the number of irrigations was four; the total quantity of water supplied was 432 m<sup>3</sup> per dunum or 10.38 m<sup>3</sup> per tree. These quantities are between the quantities supplied to 1A and 1B of the same year. The exceptional winter irrigation is not included in the above figures.

#### INVESTIGATION No. 2b.

The investigation was similar to that on plot 2a but the soil is much heavier. The plot is situated in the southern triangular part of the grove. The number of trees in 1931—32 was 165 grape-fruit budded on sour stock and 379 Shamouti budded on sour stock.

The area is 3.96 dunums grape-fruit and 9.10 dunums Shamouti. The water was equally distributed over the whole area of 13.06 dunums, by furrow irrigation.

The distribution on the plot was the same as for Experiment No. 1. i.e. in 1931 two furrows between the rows and in 1932 four furrows. The grape fruit bore fruit in 1931.

In 1931 the average interval between two irrigations was 38.7 days. The quantity of water used in every irrigation varied from 40.7 to 48.5 m<sup>3</sup>/dunum. The number of irrigations was four and the total quantity of water supplied per dunum during the season was 176.4 m<sup>3</sup> or 4.25 m<sup>3</sup> per tree.

In 1932 the figures were as follows :—

Average interval between irrigations : 33.8 days; quantity of water per irrigation varied between 61.4 and 78.1 p/d. Number of irrigations were five; total quantity of water per dunum per season 350.5 m<sup>3</sup> or 8.43 m<sup>3</sup> per tree.

The Shamouti trees did not bear fruit to an appreciable extent in this year.

In 1933 the area was slightly increased by the addition of 23 Shamouti trees budded in the autumn of 1930 in the grove. These were irrigated in 1933 with the other trees and the total area was 3.96 dunums Grape fruit, and 9.65 dunums Shamouti on sour stock.

The figures for irrigation in this year were as follows :—

Average interval between two irrigations 34.2 days; quantity of water per dunum per irrigation varied between 67.1 and 85.3 m<sup>3</sup>; number of irrigations was five (plus one additional winter irrigation owing to drought). Total quantity of water in the season — the extra irrigation not counted — 380 m<sup>3</sup> per dunum or 9.13 m<sup>3</sup> per tree.

The Shamouti trees bore a considerable quantity of fruit in this year.

#### INVESTIGATION No. 2c/2e.

The investigation was similar to that on plot 2a/2d i.e. general practice with basin irrigation in the years 1931 and 1932; furrow irrigation since 1933.

The plot is situated south-west of the pumping station and the soil is heavy like that of plot 2b. The trees are grape fruit planted out grafted on sour stock. Number of trees is 235 covering 5.64 dunums.

In 1931—32 the basin system as described in section 5 was used. The average interval between two irrigations was 39 days; the quantity of water for one irrigation varied between 49.6 and 53.8 m<sup>3</sup> per dunum. Number of irrigations was four, total amount of water was 209.3 m<sup>3</sup> per dunum per season or 5.02 m<sup>3</sup> per tree which is slightly more than that used for plot 2b.

The trees bore fruit during this year.

In 1932 the average interval between two irrigations was 35.2 days. The quantity of water for one irrigation varied between 61 and 83.4 m<sup>3</sup> per dunum. Number of irrigations was six; total quantity of water 439.4 m<sup>3</sup> per dunum per season or 10.58 m<sup>3</sup> per tree which is considerably more than the quantity used in the furrow irrigation of plot 2b.

In 1933 the basin irrigation was dropped as it was in plot 2a/2d, and furrow irrigation as described in section 5 was followed. The number of furrows was four in the row and the experiment was now called 2e.

The average interval between two irrigations was 29.4 days. The quantity of water for one irrigation varied between 70.1 and 104 m<sup>3</sup> per dunum. Number of irrigations was six, total quantity of water was 482.1 m<sup>3</sup> per dunum per season or 11.56 per tree. This is but slightly more than the quantity used for the plot in 1932 under basin irrigation although the trees were much larger and bore very much more fruit.

In summary the experimental plots may be described as follows :

INVESTIGATION No. 1. Light soil. Furrow irrigation with two different allowances of water, Plot 1A getting the smaller allowance and Plot 1B the larger. A portion of Plot A called Plot A1 received in 1933 a smaller allowance than the rest of the plot.

INVESTIGATION No. 2. *Plot 2a* which, when enlarged and passed to furrow irrigation, was called plot 2d :— Investigation into general practice on light soil. *Plot 2b* :— Investigation into general practice on heavy soil under furrow irrigation. *Plot 2c* :— Investigation into general practice in basin irrigation on heavy soil. In 1933 basin irrigation was dropped and furrow irrigation used. The plot was then called 2e.

## 7. INVESTIGATION INTO SOIL MOISTURE.

- A. It was desired to ascertain (a) the percentage of soil moisture during the irrigation period in the experimental plots at different depths and at varying distances from the trees and (b) if possible, the relation between moisture content and wilting point.
- B. The difference, if any, in moisture content immediately below and between the furrows.
- C. The moisture content in the rows at varying distances from the irrigation fitting.
- D. The variation in moisture content of the soil under irrigation at different intervals.
- F. The movement of water from the furrows into the surrounding soil.

The procedure was as follows :— Soil samples were taken at the depths, 60 cms. 100 cms and 120 to 130 cms, by means of a soil auger. Work was commenced in May 1933, and although in general, stopped following the last irrigation, continued in some places throughout the year. The soil was put into small metal boxes and weighed immediately in a small laboratory attached to the grove for this and other physiological investigations. After being dried for four hours at 105° the samples were weighed again. Drying was continued until a constant weight was found. Moisture, being the difference between the wet and the dry weight, was expressed in percentages of the dry weight. The samples were taken at varying distances from the trees as shown in the following sketch. (Page 9).

The tests were carried out on light soil plots 1A, 1B and 2d and on the heavy soil plot 2b. They were always made at the same tree in each plot and were continued at the points A and B until the beginning of October. Some extra tests were made on plot 1A at two additional trees at points A and B, from 4th August to 3rd October. On plots 2d and 2b the same extra tests were made ; those in plot 2d from 31st July to 25th September and in plot 2b from 6th August to 28th September. At the tree under test in plot 1B, tests were made at three additional points A<sup>1</sup>, B<sup>1</sup>, and C<sup>1</sup> — from 9th August to 24th September. (See tables Nos. 1a, 1b, 1c and 2, 3, 4 and 5).

*Test A.* Distribution at different depths :— 30 to 60 cms. The maxima and minima were always higher at 60 than at 30 cm except at the reading on heavy soil at point B. This was to be expected since the top soil is very much coarser than that at 60 cms. and evaporation is much freer.

### LIGHT SOIL.

The following tables Nos. 1a, 1b and 1c show the moisture content at different periods ranging from 24 to 39 days after irrigation at various points and depths in light soil.

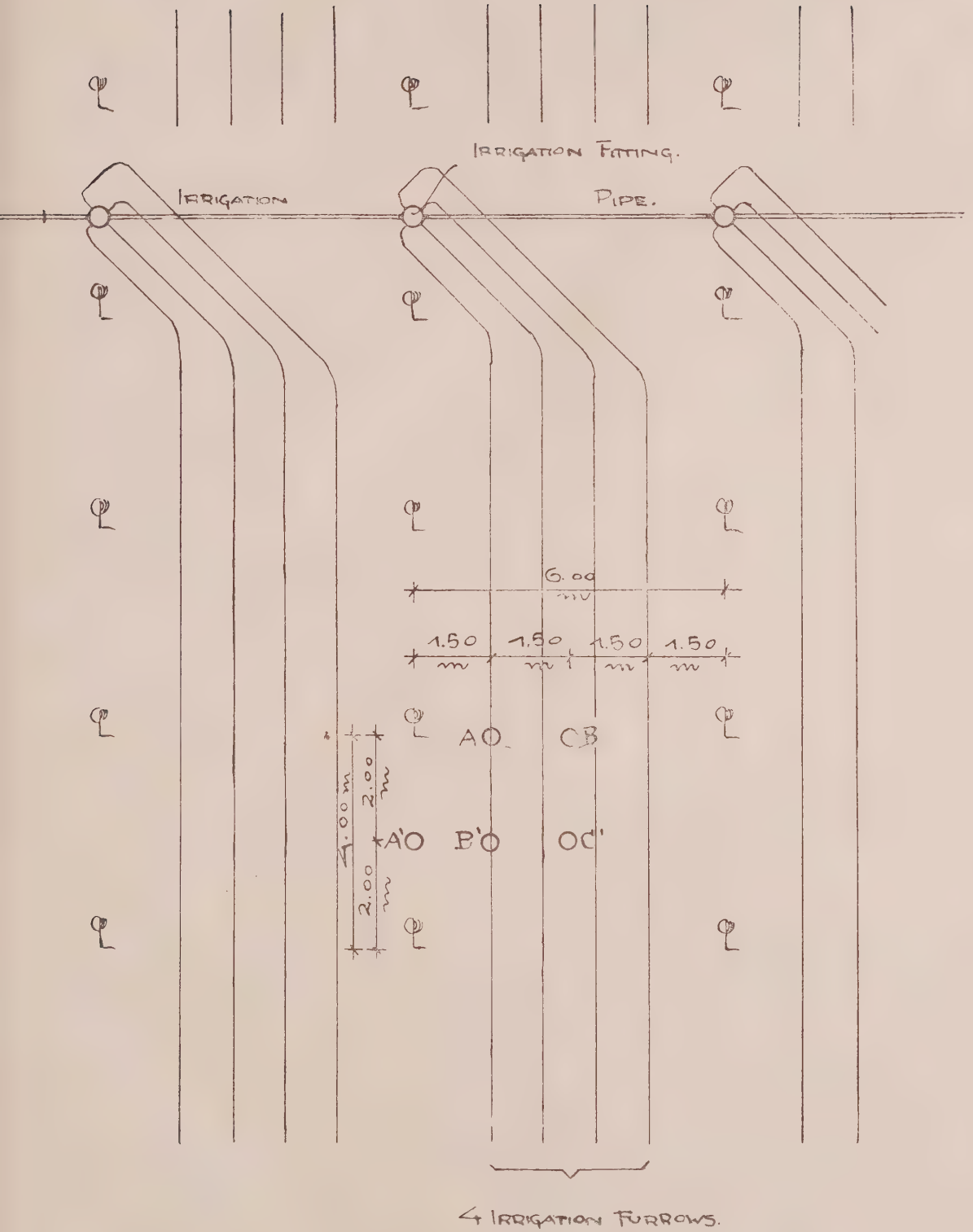
TABLE No. 1a.

Plot 1A, light soil, low water duty.

Row No. 13, Tree No. 7. Moisture content in %.

| Depth<br>in<br>cms. | 39 days after<br>1st and 3 days<br>before 2nd irr. |      | 32 days after<br>2nd and 14 days<br>before 3rd irr. |      | 30 days after<br>3rd irrigation |      |
|---------------------|----------------------------------------------------|------|-----------------------------------------------------|------|---------------------------------|------|
|                     | P O I N T S                                        |      | P O I N T S                                         |      | P O I N T S                     |      |
|                     | A.                                                 | B.   | A.                                                  | B.   | A.                              | B.   |
| 30 cm.              | 2.5                                                | 4.0  | 3.2                                                 | 8.8  | 5.1                             | 4.7  |
| 60 cm.              | 5.6                                                | 11.5 | 11.8                                                | 12.6 | 10.4                            | 11.2 |
| 100 cm.             | 15.3                                               | 13.0 | 15.2                                                | 13.9 | 15.5                            | 13.5 |
| 120 cm.             | 13.4                                               | 13.2 | 13.9                                                | 11.4 | 12.4                            | 12.8 |





Sketch showing the situation of the points A, B, A', B', and C', relative to the trees and the irrigation furrows.

TABLE No. 1b

Plot 1B. Light soil, high water duty,

Row No. 13, Tree No. 7.

| Depth<br>in<br>cms. | 24 days after<br>1st and 11 days<br>before 2nd irr. |      | 34 days after<br>2nd and 1 day<br>before 3rd irr. |      | 31 days after<br>3rd and 8 days<br>before 4th irr. |      |
|---------------------|-----------------------------------------------------|------|---------------------------------------------------|------|----------------------------------------------------|------|
|                     | P O I N T S                                         |      | P O I N T S                                       |      | P O I N T S                                        |      |
|                     | A.                                                  | B.   | A.                                                | B.   | A.                                                 | B.   |
| 30 cm.              | 4.9                                                 | 8.4  | —                                                 | 3.9  | 4.8                                                | 4.7  |
| 60 cm.              | —                                                   | 10.5 | 9.6                                               | 4.5  | 8.3                                                | 7.1  |
| 100 cm.             | 13.2                                                | 14.0 | 10.9                                              | 11.2 | 12.5                                               | 14.9 |
| 125-130             | 12.8                                                | 14.1 | 11.9                                              | 13.4 | 12.4                                               | 13.0 |

| Depth<br>in<br>cms. | 34 days after 2nd<br>and one day before<br>3rd irrigation |                |                | 31 days after 3rd<br>and 8 days before 4th<br>irrigation. |                |                |
|---------------------|-----------------------------------------------------------|----------------|----------------|-----------------------------------------------------------|----------------|----------------|
|                     | P O I N T S                                               |                |                | P O I N T S                                               |                |                |
|                     | A <sup>1</sup>                                            | B <sup>1</sup> | C <sup>1</sup> | A <sup>1</sup>                                            | B <sup>1</sup> | C <sup>1</sup> |
| 30 cm.              | 5.4                                                       | 4.0            | 4.5            | 5.0                                                       | 4.8            | 4.6            |
| 60 cm.              | 5.0                                                       | 6.4            | 9.4            | 6.6                                                       | 4.8            | 9.3            |
| 100 cm.             | 12.9                                                      | 11.0           | 14.1           | 14.1                                                      | 11.3           | 12.9           |
| 125-130             | 12.2                                                      | 13.5           | 13.1           | 13.2                                                      | 13.3           | 14.0           |

TABLE No. 1c.

Plot No. 2d. Light soil. General practice.

Row No. 12. Tree No. 23.

| Depth<br>in<br>cms. | 32 days after<br>1st and 1 day before<br>2nd irrigation. |      | 24 days after 2nd<br>and 11 days before<br>3rd irrigation. |      | 37 days after 3rd<br>and 2 days before<br>4th irrigation. |      |
|---------------------|----------------------------------------------------------|------|------------------------------------------------------------|------|-----------------------------------------------------------|------|
|                     | P O I N T S                                              |      | P O I N T S                                                |      | P O I N T S                                               |      |
|                     | A.                                                       | B.   | A.                                                         | B.   | A.                                                        | B.   |
| 30 cm.              | 4.2                                                      | 4.3  | —                                                          | 10.0 | 2.3                                                       | 10.8 |
| 60 cm.              | 5.6                                                      | 11.8 | 8.2                                                        | 10.9 | 8.5                                                       | 12.8 |
| 100 cm.             | 7.2                                                      | 10.1 | 11.1                                                       | 13.0 | 10.3                                                      | 10.9 |
| 125-130             | —                                                        | —    | 9.3                                                        | 10.1 | 7.5                                                       | 8.9  |

Row No. 12. Tree No. 17.

| Depth<br>in<br>cms. | 24 days after 2nd<br>and 11 days before<br>3rd irrigation. |      | 37 days after 3rd<br>and 2 days before<br>4th irrigation. |      |
|---------------------|------------------------------------------------------------|------|-----------------------------------------------------------|------|
|                     | P O I N T S                                                |      | P O I N T S                                               |      |
|                     | A.                                                         | B.   | A.                                                        | B.   |
| 30                  | 4.5                                                        | 2.4  | 5.5                                                       | 7.3  |
| 60                  | 9.4                                                        | 11.7 | 10.4                                                      | 11.7 |
| 100                 | 13.1                                                       | 12.3 | 13.6                                                      | 7.8  |
| 130                 | 12.5                                                       | 12.5 | 11.7                                                      | 13.2 |



Row No. 12. Tree No. 30.

| Depth<br>in<br>cms. | 24 days after 2nd<br>and 11 days before<br>3rd irrigation. | 37 days after 3rd<br>and 2 days before<br>4th irrigation. |
|---------------------|------------------------------------------------------------|-----------------------------------------------------------|
|                     | P O I N T S                                                | P O I N T S                                               |
|                     | A. B.                                                      | A. B.                                                     |
| 30                  | 6.6 8.0                                                    | 10.4 5.9                                                  |
| 60                  | 11.0 13.1                                                  | 12.4 11.0                                                 |
| 100                 | 13.0 10.6                                                  | 11.7 10.7                                                 |
| 130                 | 11.2 10.6                                                  | 10.6 9.8                                                  |

It was desired to ascertain whether at any time during the year there was a lack of moisture in the soil approaching wilting point. This question was answered in a manner through some trees reaching the wilting point (the only trees which did so in the grove) in a part of the grove near a manure pit which had been opened and apparently had the effect of drying out the soil. This happened in plot 1A (light soil).

The moisture content at this place was as follows :—

TABLE No. 2.

1st tree on the 2nd row i.e. 7.5 m. from the pit.

|         |         |           |      |            |      |
|---------|---------|-----------|------|------------|------|
| Depth : | 60 cm.  | Point A : | 5.6% | Point A1 : | 2.3% |
|         | 100 cm. |           | 3.1% |            | 3.4% |
|         | 130 cm. |           | 3.5% |            | 6.9% |

The average of the minima according to these tables (except table No. 2) and further records was as follows :—

TABLE No. 3.

|       |         |       |   |     |
|-------|---------|-------|---|-----|
| Depth | 60 cms  | 8.5%  | ± | 0.7 |
|       | 100 cms | 11.7% | ± | 0.8 |
|       | 130 cms | 11.7% | ± | 0.8 |

The absolute minimum (except at the manure pit) was as follows :—

TABLE No. 4.

|       |         |      |
|-------|---------|------|
| Depth | 60 cms  | 5%   |
|       | 100 cms | 7.2% |
|       | 130 cms | 7.5% |

The absolute minimum of moisture found at 60 cms depth, apparently the most important depth for water absorption by the roots (see below) was, as stated above, 5%. The reading was taken on August 9th in plot 1B, tree 7, row 12 at the point A<sup>1</sup>. The moisture content taken at the same time, same depth and same tree Pt. A was 9.6% and at Pt. B 6.4%.

Another low moisture content at 60 cm. depth was found on the 16th July in plot 1A at tree No. 7, row 13 point A<sup>1</sup> viz. 5.6%. The moisture content at Pt. C<sup>1</sup> at the same tree was 11.5%.

On these figures it appears that there was at no time any approach to dangerous scarcity of soil moisture on light soil except at the pit where at Pt. A<sup>1</sup> it was 2.3%. This of course was due to the special circumstances.

It will be noted on reference to the tables that the moisture content in the lower layers of the soil varied much less in the interval between two irrigations than that in the 30 and 60 cm. layers. It would appear that the variations in moisture are less at Point B than at Point A and have their maximum at Point A<sup>1</sup> and B<sup>1</sup> where the root system of two trees meet.

#### HEAVY SOIL.

The following table shows figures for heavy soil obtained towards the end of an irrigation period.

TABLE No. 5.

Plot 2b. Heavy soil. General practice. Oranges.

| Row No. 1. Tree No. 1. |                                                           |      | Row No. 1. Tree No. 11.                                   |      |                                                           |    |
|------------------------|-----------------------------------------------------------|------|-----------------------------------------------------------|------|-----------------------------------------------------------|----|
| Depth<br>in<br>cms.    | 34 days after 1st<br>and 2 days before<br>2nd irrigation. |      | 19 days after 3rd<br>and 6 days before<br>4th irrigation. |      | 32 days after 4th<br>and 8 days before<br>5th irrigation. |    |
|                        | P O I N T S                                               |      | P O I N T S                                               |      | P O I N T S                                               |    |
|                        | A.                                                        | B.   | A.                                                        | B.   | A.                                                        | B. |
| 30                     | 13.3                                                      | 19.7 | 11.4                                                      | 11.0 | 9.4                                                       | —  |
| 60                     | 19.2                                                      | 21.8 | 19.9                                                      | 11.7 | 15.5                                                      | —  |
| 100                    | 18.4                                                      | 17.6 | 18.9                                                      | 17.1 | 13.2                                                      | —  |
| 120                    | 19.2                                                      | 20.6 | 15.5                                                      | 14.7 | 13.2                                                      | —  |

Row No. 1. Tree No. 21.

| Depth<br>in<br>cms. | 19 days after 3rd<br>and 6 days before<br>4th irrigation. |      | 32 days after 4th<br>and 8 days before<br>5th irrigation. |      |
|---------------------|-----------------------------------------------------------|------|-----------------------------------------------------------|------|
|                     | P O I N T S                                               |      | P O I N T S                                               |      |
|                     | A.                                                        | B.   | A.                                                        | B.   |
| 30                  | 15.9                                                      | 10.6 | 8.2                                                       | 14.9 |
| 60                  | 12.0                                                      | 15.7 | 10.7                                                      | 12.8 |
| 100                 | 12.5                                                      | 12.3 | —                                                         | 11.0 |
| 120                 | 10.1                                                      | 11.3 | —                                                         | 10.7 |

If the moisture on the light soil plot 1A Row No. 1, tree No. 7, point A, at 39 days after the first and 3 days before the second irrigation, be compared with that observed on heavy soil plot 2b, row No. 1, tree No. 1, point A, 34 days after first and 2 days before 2nd irrigation (both at 60 cms deep), we find in light soil 5.6% and in heavy soil 19.2%. It appears that in this case the interval between first and second irrigation might have been considerably extended on the heavy soil without harming the trees.

*Test B.* The question as to difference in soil moisture shortly after irrigation immediately below the furrows and between them is dealt with in table No. 6, giving three sets of figures. In every case the Pt. A is below the furrow and the Pt. B between furrows.

TABLE No. 6.

Plot 2d. Light Soil. Row No. 12.

Average of three points.

| Depth<br>in<br>cms. | 3 days after 3rd<br>irrigation. |        | 5 days after 4th<br>irrigation. |        |
|---------------------|---------------------------------|--------|---------------------------------|--------|
|                     | Pt. A.                          | Pt. B. | Pt. A.                          | Pt. B. |
| 30                  | 11.6                            | 10.2   | 13.4                            | 10.1   |
| 60                  | 15.1                            | 13.9   | 14.7                            | 16.2   |
| 100                 | 13.4                            | 14.6   | 11.2                            | 13.3   |
| 130                 | 12.0                            | 12.7   | 12.0                            | 12.0   |

Plot 2b. Heavy Soil. Row No. 1. Average of three points.

| Depth<br>in<br>cms. | 4 days after 3rd<br>irrigation. |        |
|---------------------|---------------------------------|--------|
|                     | Pt. A.                          | Pt. B. |
| 30                  | 16.5                            | 16.5   |
| 60                  | 16.6                            | 19.1   |
| 100                 | 16.3                            | 16.1   |
| 130                 | 13.2                            | 14.0   |

In the light soil there is at 30 cms a slight difference in favour of the Pt. A (below the furrow). At 60 cms. the average of the two readings is slightly in favour of the Pt. B (between the furrows). At the lower depths there is even a smaller difference. In the heavy



soil at the 30 cms. layer Pts. A and B are the same and at 60 cms. the point B has the greater moisture. From these figures and from others obtained, it would appear that, for all practical purposes, the soil is as well supplied between as below the furrows.

*Test C.* For the investigation of the moisture content in the rows at varying distances from the irrigation fitting, tests were made in plots 1A, 2d and 2b in one row of trees as shown in the following tables 7a, 7b and 7c.

TABLE No. 7a.

Plot 1A. Light soil. Low water duty.

Row No. 13. Five days after 3rd irrigation.

| Depth<br>in<br>cms. | Tree No. 13 being the<br>tree nearest to the<br>irrigation fitting. |      | Tree No. 7 being<br>ninth tree from<br>irrigation fitting. |      |
|---------------------|---------------------------------------------------------------------|------|------------------------------------------------------------|------|
|                     | P O I N T S                                                         |      | P O I N T S                                                |      |
|                     | A.                                                                  | B.   | A.                                                         | B.   |
| 30                  | 13.0                                                                | 10.9 | 8.5                                                        | 10.4 |
| 60                  | 17.3                                                                | 15.4 | 15.8                                                       | 14.2 |
| 100                 | 12.9                                                                | 14.3 | 14.1                                                       | 14.9 |
| 130                 | 13.4                                                                | 13.0 | 13.6                                                       | 14.5 |

TABLE No. 7b.

Plot 2d. Light soil. General practice.

Row No. 12.

| Three days<br>after 3rd<br>irrigation.<br>Depth<br>in<br>cms. | Tree No. 17, being<br>tree nearest to the<br>irrigation fitting. |      | Tree No. 23, being<br>7th tree from the<br>irrigation fitting. |      | Tree No. 30, being 14th<br>tree i.e. the farthest<br>from the fitting. |      |
|---------------------------------------------------------------|------------------------------------------------------------------|------|----------------------------------------------------------------|------|------------------------------------------------------------------------|------|
|                                                               | P O I N T S                                                      |      | P O I N T S                                                    |      | P O I N T S                                                            |      |
|                                                               | A.                                                               | B.   | A.                                                             | B.   | A.                                                                     | B.   |
| 30                                                            | 10.6                                                             | 9.6  | 10.6                                                           | 10.3 | 13.5                                                                   | 10.7 |
| 60                                                            | 15.4                                                             | 15.0 | 14.3                                                           | 12.8 | 15.7                                                                   | —    |
| 100                                                           | 14.3                                                             | 13.1 | —                                                              | —    | 12.5                                                                   | 16.1 |
| 130                                                           | 13.6                                                             | 13.3 | 10.2                                                           | —    | 12.0                                                                   | 12.1 |
| Five days<br>after 4th<br>irrigation.                         |                                                                  |      |                                                                |      |                                                                        |      |
| 30                                                            | 10.7                                                             | 12.6 | 8.2                                                            | 7.2  | 11.2                                                                   | 10.5 |
| 60                                                            | 14.3                                                             | 15.8 | 13.4                                                           | 15.9 | 16.5                                                                   | 17.1 |
| 100                                                           | 8.3                                                              | 13.6 | 12.8                                                           | 11.7 | 12.6                                                                   | 14.6 |
| 130                                                           | 15.5                                                             | 15.7 | 8.2                                                            | 10.0 | 12.7                                                                   | 11.0 |

TABLE No. 7c.

Plot 2b. Heavy soil. General practice. Oranges.

Row No. 1.

| Four days<br>after 3rd<br>irrigation<br>Depth<br>in cms. | Tree No. 21 being<br>nearest irrigation<br>fitting. |      | Tree No. 16 being<br>6th tree from the<br>irrigation fitting. |      | Tree No. 11 being tree<br>farthest from the<br>irrigation fitting. |      |
|----------------------------------------------------------|-----------------------------------------------------|------|---------------------------------------------------------------|------|--------------------------------------------------------------------|------|
|                                                          | P O I N T S                                         |      | P O I N T S                                                   |      | P O I N T S                                                        |      |
|                                                          | A.                                                  | B.   | A.                                                            | B.   | A.                                                                 | B.   |
| 30                                                       | 16.6                                                | 17.1 | 17.5                                                          | 18.2 | 15.5                                                               | 14.3 |
| 60                                                       | 18.8                                                | 18.8 | 17.0                                                          | 19.4 | 14.0                                                               | —    |
| 100                                                      | 13.5                                                | 12.6 | 16.6                                                          | 15.6 | 18.8                                                               | 20.0 |
| 130                                                      | 11.3                                                | 11.9 | 14.4                                                          | 16.0 | 14.0                                                               | —    |
| Ten days<br>after 4th<br>irrigation.                     |                                                     |      |                                                               |      |                                                                    |      |
| 30                                                       | 15.0                                                | 15.6 | 14.8                                                          | 18.8 | 14.4                                                               | 16.4 |
| 60                                                       | 17.7                                                | 9.2  | 17.8                                                          | 18.4 | 21.1                                                               | —    |
| 100                                                      | 13.3                                                | 13.9 | 14.3                                                          | 15.0 | 16.0                                                               | 18.6 |
| 130                                                      | 10.8                                                | 11.1 | 14.1                                                          | 13.4 | 14.3                                                               | 14.7 |

It appears from these tables that on light soil the middle of the row receives slightly less water than the beginning and the end of it; whereas in the heavy soil the end of the row receives the lesser quantity. The difference is so small however, that it may be considered that the distribution of water by furrow irrigation from beginning to the end of the furrow is equal enough for all practical purposes.

*Test D.* Investigations were made to ascertain the soil moisture under irrigation at different intervals. Tests were made on plots 1A (Low water duty), 1B (High water duty), and 2d (General Practice), all on light soil.

The minima of soil moisture towards the end of the interval between two irrigations at the point A at 60 cms. depth were as follows :—

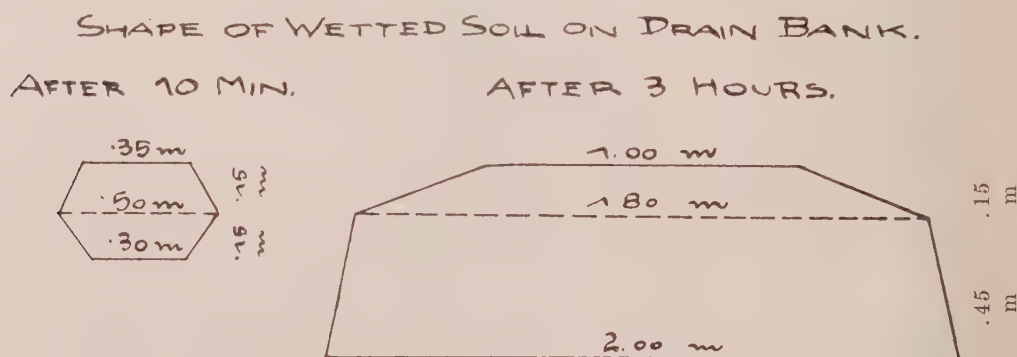
TABLE NO. 8.

| Plot No. | Date                                                   | Moisture % | Quantity of water in preceding irrigation<br>m <sup>3</sup> per dunum. |
|----------|--------------------------------------------------------|------------|------------------------------------------------------------------------|
| 1A       | 39 days after 1st,<br>3 days before 2nd<br>irrigation. | 5.6%       | 131.8 m <sup>3</sup>                                                   |
| 2d       | 32 days after 1st,<br>1 day before<br>2nd irrigation.  | 5.6%       | 128.5 m <sup>3</sup>                                                   |
| 1B       | 34 days after 2nd,<br>1 day before<br>3rd irrigation.  | 9.6%       | 109.0 m <sup>3</sup>                                                   |
| 2d       | 37 days after 3rd,<br>2 days before<br>4th irrigation. | 8.5%       | 100.6 m <sup>3</sup>                                                   |

It is difficult to draw any definite conclusion from these figures. Note however, that the moisture content at 60 cms. was the same in plot 1A 39 days after irrigation as in plot 2d 32 days after irrigation.

*Test E.* Investigation into the movement of water from the furrow into the surrounding soil was made as follows :—

A small pit similar in size to a furrow was made close to the steep bank of an earth drain in the light soil. The pit was kept full of water during several hours and the area wetted by seepage was observed on the bank of the drain. The size of the wetted area at 10 minutes and at 3 hours after the commencement of the test is shown in the sketch below :—



An experiment was made in the laboratory to examine this point further. A box with one glass front was filled with light soil and a furrow was made through the soil. The furrow was kept full of water and percolation observed on the glass front. Progress was similar to that observed in the field test. The increase in wetted area was gradual and the moisture spread latitudinally to a considerable distance.

This substantiates the opinion formed already according to Test B and experience in the grove, that there is satisfactory spread of water from furrows throughout.

## 8. COST OF IRRIGATION AND COMPARISON BETWEEN FURROW AND BASIN IRRIGATION.

In addition to the evidence produced in this series of experiments that the quantity of water given to citrus may be considerably reduced below the general practice without



damage to the trees (see section 10) there is evidence of the advantage of the furrow system over the basin system which is still used almost everywhere in Palestine.

Furrow irrigation is irrigation by means of small streams of water running at low velocity in furrows between the rows of trees, there being no storage of water in basins around the trees. For equal distribution in the soil, 2 to 4 furrows are required between two rows of trees. The system requires fittings on the pipes which will enable the discharge from the pipe to be divided into a certain number of small streams which should be as equal as possible. The circular boxes described in section 4 are very suitable for the purpose but it must be borne in mind that, without the four 2" outlets from these boxes, the advantages of the furrow system are not obtained. On the contrary, much harm is done by scouring in the neighbourhood of the boxes by the heavy discharge from the top of them.

Contrary to the general opinion it was found in Gan Moshe that with the proper employment of the furrow irrigation system, smaller quantities of water were required than when the basin system was used on the same light and heavy soil. Further investigation will be required to prove whether this feature will persist.

An important consideration is the cost of labour in connection with the furrow practice as compared with the basin.

Two tables, one based on conditions which may be expected in the Gan Moshe Grove in its full bearing age and the other on general Palestine irrigation practice are given.

The basis of the figures is the following :—

Cost of daily labour 200 mils per day. Daily cost of a horse for opening furrows : 300 mils. Daily capacity of a labourer :— One man digs 50 basins a day. One man controls a discharge of 75 m<sup>3</sup>/h. when irrigating in furrows and 20 to 30 m<sup>3</sup>h. in basin irrigation. Daily capacity of a horse in opening of furrows :— 6 dunums.

Figures assumed for Gan Moshe when at full bearing and given per dunum :—

| FURROW IRRIGATION                                          |            | BASIN IRRIGATION.                                 |            |
|------------------------------------------------------------|------------|---------------------------------------------------|------------|
| Five irrigations per season<br>at 140 m <sup>3</sup> each. |            | Six irrigations<br>at 130 m <sup>3</sup> each.    |            |
| Cost of three furrowings                                   | L.P. 0.250 | Cost of digging and main-<br>taining 41.6 basins  | L.P. 0.200 |
| Cost of 5 times irrigation<br>1 h. 55 min. each :          | L.P. 0.240 | Cost of six times irrigation<br>5 h. 10 min. each | L.P. 0.775 |
| Total                                                      | L.P. 0.490 | Total                                             | L.P. 0.975 |

General practice in Palestine, figures per dunum :

| Eight irrigations per season at 120 m <sup>3</sup> each. |            | Ten irrigations per season at 90 m <sup>3</sup> each |            |
|----------------------------------------------------------|------------|------------------------------------------------------|------------|
| Three times furrowing                                    | L.P. 0.250 | Digging and maintaining<br>41.6 basins               | L.P. 0.250 |
| Eight times irrigation<br>1 h. 35 min. each              | L.P. 0.317 | Ten times irrigation<br>3 h. 40 min. each.           | L.P. 0.917 |
| Total                                                    | L.P. 0.567 | Total                                                | L.P. 1.167 |

It will be noted that three furrowings are allowed for in the above calculations. As a matter of fact it is customary in this grove and indeed elsewhere to cultivate the land between irrigations and refurrow. This is however in the nature of soil treatment, not applicable every time to irrigation, and which has no equivalent in basin irrigation. The baking of the furrows must be guarded against however, and depending on the presence of that feature, the furrows may have to be remade once or twice during the season. The tables show economy in labour effected by furrow irrigation and there would appear no reason why the system should not be followed in new groves throughout the country, except in places where, due to extreme permeability of the soil, the small streams may be soaked up before reaching the end of the furrow. Even here corrective measures such as larger streams or shorter furrows, the latter involving increase in distribution pipes, may be employed.

Possibly the best recommendation for the furrow system lies in the fact that, following experience of the two methods coupled with observation as to cost and quantities of water, the managers of the Gan Moshe grove have adopted it throughout the grove.

Frequent cultivation of the soil in a grove reduces evaporation, destroys weeds — thereby conserving manure — and aerates the soil. This is simply and economically effected with furrow irrigation but is difficult and expensive with the basin system. The root system is spread over the whole of the grove at an early date thus providing a large feeding area. In

addition, if the system be carried out in the proper manner, the small streams employed obviate scouring and it can be employed on steeper slopes than those possible under basin irrigation.

The cost of the water at the well top and at the irrigation fitting is given as follows. The calculation is made for the Gan Moshe grove at full bearing age but, as will be noted in the following paragraph, the area of the grove is taken as 134 dunums in place of the actual size 83.4 dunums.

The well capacity at Gan Moshe is larger than is actually necessary and land outside the grove is also irrigated from it. Assuming a water duty of 700 m<sup>3</sup> per dunum per season the 83.4 dunums will require 58300 m<sup>3</sup> per annum. The well and the plant is capable of supplying 94000 m<sup>3</sup> which, at a similar water duty, would supply 134 dunums. The calculation is therefore made on the assumption that the well is fully exploited, i.e. irrigates 134 dunums. The number of irrigations is five at 30 days intervals with 140 m<sup>3</sup> at each irrigation. The total lift is 42 metres and includes a vacuum of 5 metres. The efficiency of the pump is very high, slightly more than 70%. The supervision of the plant is done by the foreman of the grove and, at most, two hours of his working day of eight hours is required for supervision of the plant, arranging distribution in the pipe line, recording water meter and Watt meter etc. A quarter of his time is allowed therefore during the five months of the irrigation season for the cost of supervision. Half of this time may be considered as due to supervision of the pumping plant and half for arranging distribution of water in the pipe lines. The amount of pipes and channels used in the grove and their cost, rated at present values, is as per table. Part of the pressure pipes are actually 6" and 5" steel pipes but as this type of pipe is uneconomical at the present rates, 6" spun concrete pipes are estimated throughout.

| High pressure 6" spun concrete pipes. |                  | Low Pressure 6" plain concrete pipes. |  | Open Channels. |
|---------------------------------------|------------------|---------------------------------------|--|----------------|
| Conveying pipes                       | Irrigating pipes | Irrigating pipes                      |  |                |
| Total length 324 m.                   | 500 m.           | 739 m.                                |  | 55 m.          |
| Length per dunum 3.88 m.              | 6.00 m.          | 8.68 m.                               |  | 0.66 m.        |
| Cost in L.P. per metre L.P. 0.291     | L.P. 0.391       | L.P. 0.221                            |  | L.P. 0.100     |
| Total cost per dunum L.P. 1.129       | L.P. 2.346       | L.P. 1.958                            |  | L.P. 0.066     |

The total cost of irrigation lay-out, if made to day when prices are lower than in 1929-30 would therefore be L.P. 5.499 per dunum. The cost for a grove similar to the Gan Moshe grove would be L.P. 5.499 × 134 du., approximately L.P. 737. Since there is no appreciable alteration in the cost of well, bore, machinery and engine house since 1929-30, the original cost is given as follows.

Calculation of price of water at well top and at the irrigation fitting for a grove of 134 dunums at 6% interest on capital invested is given as follows :—

| I t e m                                                        | Total cost. | Cost per dunum. | Interest depreciation and repairs | L.P per annum. |
|----------------------------------------------------------------|-------------|-----------------|-----------------------------------|----------------|
| Shaft Well                                                     | L.P. 282    | L.P. 2.1        | 7½% p.a.                          | L.P. 20.4      |
| Bore                                                           | 243         | 1.8             | 9½% p.a.                          | 23.1           |
| Machinery :<br>Electric Motor<br>and Horizontal<br>Cent. pump. | 260         | 1.9             | 12 % p.a.                         | 31.2           |
| Engine House                                                   | 145         | 1.1             | 8½% p.a.                          | 12.3           |
| Connection to<br>Power Dist.<br>Lines.                         | 41          | 0.3             | 6 % p.a.                          | 2.5            |
| Total                                                          | L.P. 971    | L.P. 7.2        |                                   | L.P. 89.5      |
| Pipe Lines and<br>Channels.                                    | L.P. 737    | L.P. 5.5        | 7½% p.a.                          | L.P. 55.3      |
| Grand Total :                                                  | L.P.1708    | L.P.12.7        |                                   | L.P.144.8      |



The yearly expenditure, due to interest, depreciation and repair for water at the well top for a 134 dunum grove is therefore L.P. 89.5 and at the irrigation fitting L.P. 144.8.

TOTAL COST OF WATER BASED ON AN ALLOWANCE OF 700 m<sup>3</sup> PER ANNUM PER DUNUM  
ON A 134 DUNUM GROVE AT FULL BEARING UNDER FURROW IRRIGATION.

| Item                                         | At Top of Well | At Irrigation Fitting |
|----------------------------------------------|----------------|-----------------------|
| Interest, Depreciation and Repair.           | L.P. 89.5      | L.P. 144.8            |
| Supervision of Plant                         | 7.5            | 7.5                   |
| Power — 17,600 kWh calculated at 1934 Rates. | 117.9          | 117.9                 |
| Lubrication, etc.                            | 3.9            | 3.9                   |
| TOTAL for 94000 m <sup>3</sup> per annum     | L.P. 218.8     | L.P. 274.1            |
| Cost per dunum :                             | L.P. 1.63      | L.P. 2.05             |
| Cost per metre Cube :                        | L.P. 0.0023    | L.P. 0.0029           |

These figures may be compared in the following calculation with those for the same grove irrigated on the basin system with a water duty of 900 m<sup>3</sup> per dunum per season, given in ten irrigations at 21 day intervals which may be taken as general irrigation practice in Palestine.

COST OF WATER.

| Item                                           | Cost at Well Top | Cost at Irrigation Fitting. |
|------------------------------------------------|------------------|-----------------------------|
| Interest, Depreciation and Repairs.            | L.P. 93.4        | L.P. 148.7                  |
| Supervision                                    | 10.5             | 10.5                        |
| Power — 22700 kWh. at 1934 rates.              | 134.9            | 134.9                       |
| Lubrication, Etc.                              | 4.7              | 4.7                         |
| TOTAL cost for 120600 m <sup>3</sup> per annum | L.P. 243.5       | L.P. 298.8                  |
| Cost per dunum :                               | L.P. 1.82        | L.P. 2.23                   |
| Cost per metre cube :                          | L.P. 0.00202     | L.P. 0.00248                |

The alteration in the cost of water is in the item depreciation and repair on machinery which, on account of the longer pumping period, is increased by 1½%; in supervision which is a quarter of the foreman's time for 210 days in place of 150 days and in power and lubrication. The total quantity of water pumped is 120,600 m<sup>3</sup> in place of 94000 m<sup>3</sup>.

The difference between irrigation costs per dunum is, at the irrigation fitting, 180 mils.

### 9. GROWTH OF TREES FROM START OF INVESTIGATIONS; YIELD, ETC.

Many of the orange trees were showing new sprouts at the time of planting. The trees in the experimental plots were not pruned and the growth of most of these new sprouts was not interrupted. Later on in the summer the resultant branches were of normal size. Those sprouts which suffered from the transplanting died back to the first vegetation of the year and fell off. The healthy branches formed a thin layer of cork at the junction and showed new vegetation in six to eight weeks after planting. New root development was observed from two to three weeks after planting; that is to say new roots penetrated the soil round the planting ball.

In 1931 and 1932 the growth of the trees was completely satisfactory and in spring 1932 there was some flowering and a small quantity of fruit was set.

In 1933 there was quite extensive flowering and a very reasonable crop of fruit was obtained without any damage to the growth of the trees.

There was similarly satisfactory development of the root system during these two years and close investigation in 1933 showed a dense network of roots to a depth of about 1.30 m. The greatest density of roots was at a depth between 50 to 80 cms. The lateral spread of the roots extended to three metres from the tree trunk. The whole space between trees was filled with roots and full advantage was thus taken of irrigation and manuring over the whole area.

The grapefruit which was pruned before planting showed a renewal of growth six weeks after planting which proceeded vigorously during the year. Growth was equally satisfactory in 1931, and in 1932 a reasonably good crop of fruit was secured. The root spread was somewhat quicker and deeper than that of the oranges.

The several plots did not show any marked difference in accordance with the quantity

of water supplied. There was no less development on the minimum duty plot than on the general practice or maximum duty plots.

The following table shows yields of fruit obtained in 1934/35 and is inserted notwithstanding the fact that the details regarding the 1934 work are not recorded in this paper. The quantity gives the total of ungraded fruit picked.

It will be of interest however to note briefly features that occurred in 1934.

An endeavor was made to maintain the two plots 1A and 1B on a low and high water duty basis. The rotation for the low water duty was fixed at 55 days and the high water duty at 45 days. The quantity of water to be given each plot was 110 to 120 m<sup>3</sup> per dunum at each irrigation. It was not found possible to maintain the 55 days interval in the plot 1A. The actual average interval was 51 days. Moreover, during the irrigation it was found that the allotted quantity of water was insufficient to complete the irrigation of the plot. More water had to be supplied therefore and the total quantity of water supplied during the season was actually slightly more than that supplied in 1B.

The final irrigation to plot 1A was given on September 15th after an interval of 55 days. Rain is normally expected in early November but rain in quantity did not fall until 6th December. It was absolutely necessary therefore to irrigate and this was done on 14th November, after an interval of 60 days. In effect both plots received 4 irrigations.

Fruit was picked, numbered and sized from three groups of nine trees each in plot 1A and plot 1B and from one group of nine trees in plot 2d. These groups surrounded and included trees which have been photographed each year since the commencement of the investigations.

The trees were photographed by a stand camera placed at the same distance and elevation from the tree each year from 1931. The photographs are interesting in as much as they show a similarity in development and a maintenance of the shape of each tree during the four years growth. The photographs are, of course, also proof of the satisfactory development of the trees. The two series of photographs reproduced in this report are sufficient to demonstrate the points referred to.

#### YIELD RECORDS 1934 - 35.

Plot 1A. Budded trees planted March 1930 on light soil.

Number of trees picked — 27.

| Size of Fruit<br>(No. of fruit<br>in case). | Number of fruits |                    |              | Number of cases |                    |              |
|---------------------------------------------|------------------|--------------------|--------------|-----------------|--------------------|--------------|
|                                             | Total            | Average<br>p. tree | % of<br>size | Total           | Average<br>p. tree | % of<br>size |
| 80                                          | 492              | 18.2               | 5.6          | 6.2             | 0.23               | 8.1          |
| 100                                         | 3219             | 119.0              | 36.5         | 32.2            | 1.19               | 42           |
| 120                                         | 2682             | 99.4               | 30.8         | 22.4            | 0.83               | 29.2         |
| 140                                         | 1006             | 37.2               | 11.5         | 7.2             | 0.27               | 9.5          |
| 150                                         | 727              | 27.0               | 8.3          | 4.8             | 0.18               | 6.3          |
| 160                                         | 610              | 22.6               | 7.0          | 3.8             | 0.14               | 4.9          |
| Totals                                      | 8736             | 323.4              | 100          | 76.6            | 2.84               | 100          |
| Per dunum                                   | 13460            |                    |              | 118             |                    |              |

Maximum yield per photographed tree 405 oranges } Out of three trees.  
 Minimum " " " 255 " }  
 Average size of case 114 " per case over 27 trees.

Note:— There were among the 27 trees, 6 trees budded in situ in autumn 1930.

Plot 1B. Budded trees planted March 1930 on light soil.

Number of trees picked — 27.

| Size of Fruit<br>(No. of fruit<br>in case). | Number of fruits |                    |              | Number of cases |                    |               |
|---------------------------------------------|------------------|--------------------|--------------|-----------------|--------------------|---------------|
|                                             | Total            | Average<br>p. tree | % of<br>size | Total           | Average<br>p. tree | % of<br>size. |
| 80                                          | 82               | 3.0                | 0.9          | 1.0             | 0.04               | 1.4           |
| 100                                         | 1575             | 58.4               | 17.2         | 15.8            | 0.58               | 22.8          |
| 120                                         | 2603             | 96.5               | 28.4         | 21.7            | 0.80               | 31.4          |
| 140                                         | 650              | 24.1               | 7.1          | 4.6             | 0.17               | 6.6           |
| 150                                         | 2013             | 74.5               | 21.9         | 13.4            | 0.50               | 19.4          |
| 160                                         | 1173             | 43.4               | 12.8         | 7.3             | 0.27               | 10.5          |
| 180                                         | 536              | 19.9               | 5.8          | 3.0             | 0.11               | 4.3           |
| 210                                         | 527              | 19.5               | 5.8          | 2.5             | 0.09               | 3.6           |
| 240                                         | 10               | 0.4                | 0.1          | 0.04            | —                  | 0.01          |
| Totals                                      | 9169             | 339.7              | 100.0        | 69.3            | 2.56               | 100.0         |
| Per dunum                                   | 14168            |                    |              | 107             |                    |               |





Photo No. 2a.  
Tree No. 8 Row No. 8 Plot 1 B (Shamouti).  
Photographed on 8.7.1931.



Photo No. 2b.  
Tree No. 8 Row No. 8 Plot 1 B (Shamouti).  
Photographed on 22.7.1932.





Photo No. 2 c.  
Tree No. 8 Row No. 8. Plot 1 B (Shamouti).  
Photographed on 28.12.1933.



Photo No. 2 d.  
Tree No. 8. Row No. 8. Plot 1 B (Shamouti)  
Photographed on 19.11.1934.





Photo No. 6 a.  
Tree No. 4. Row No. 1. Plot 2 b/e (Grapefruit).  
Photographed on 8.7.1931.



Photo No. 6 b.  
Tree No. 4. Row No. 1. Plot 2 b/e (Grapefruit).  
Photographed on 22.7.1932.





Photo No. 6 c.  
Tree No. 4. Row No. 1. Plot 2 b/e (Grapefruit).  
Photographed on 28.12.1933.



Photo No. 6 d.  
Tree No. 4. Row No. 1. Plot 2 b/e (Grapefruit).  
Photographed on 19.11.1934.  
As tree was too big for the plate, the photograph  
No. 6 d was taken at a greater distance.



Maximum yield p. photographed tree 501 } Out of three trees  
Minimum " p. " 286 }  
Average size of case, 132 oranges per case over 27 trees.

Plot 2d. General Practice. Budded trees planted March 1930 on light soil.

Number of trees picked — 9.

| Size of Fruit<br>(No. of fruit<br>in case). | Number of fruits |                    |              | Number of cases |                    |              |
|---------------------------------------------|------------------|--------------------|--------------|-----------------|--------------------|--------------|
|                                             | Total            | Average<br>p. tree | % of<br>size | Total           | Average<br>p. tree | % of<br>size |
| 100                                         | 182              | 20.2               | 5.7          | 1.8             | 0.20               | 8.1          |
| 120                                         | 337              | 37.4               | 10.5         | 2.8             | 0.31               | 12.6         |
| 140                                         | 778              | 86.4               | 24.1         | 5.6             | 0.62               | 25.1         |
| 150                                         | 1195             | 132.8              | 37.1         | 8.0             | 0.88               | 35.8         |
| 160                                         | 366              | 40.7               | 11.4         | 2.3             | 0.25               | 10.3         |
| 180                                         | 187              | 20.8               | 5.8          | 1.0             | 0.12               | 4.5          |
| 210                                         | 173              | 19.2               | 5.4          | 0.8             | 0.09               | 3.6          |
| Totals                                      | 3218             | 357.5              | 100          | 22.3            | 2.47               | 100          |
| Per Dunum                                   | 14874            |                    |              | 102.7           |                    |              |

Average size of case : 144 oranges per case.

## 10. CONCLUSIONS.

Through this series of investigations a concise record of the irrigation of a large grove on representative soil has been obtained. That the grove has maintained excellent condition is evidenced by the yield obtained in winter 1933/34 from three year old trees which was equal to 85 boxes per dunum for oranges, and 100 boxes for grape fruit.

Possibly the most striking feature is the length of the interval between irrigations of the plots 1A and 1B which in 1933 was 44 days for plot 1A and 36 days for plot 1B. The interval was further extended in 1934.

There is no apparent difference in the appearance of the trees in plots 1A, 1B and 2d, and although there is no claim to a decision as to actual optimum duty of water in this grove, evidence is afforded of a sufficient water duty : 360 m<sup>3</sup> per irrigation season in three irrigations at 44 days interval on this type of soil in a 3 year old grove planted with budded trees.

A feature of the tests was the absence of wilting. None was observed, if one excepts a slight appearance in 1933 at midday, shortly before irrigation. This was but temporary and during the hottest period of the day.

The appearance of the grove throughout in spring 1935 continues to be excellent. It remains for future years to determine full development and yield. The yield in 1934/35 was per tree 2.8 cases of fruit for 1A and 2.6 cases for plot 1B. These figures were obtained from the average of 27 trees in each plot which were specially picked and sized. The quantities of water supplied during the irrigation season of 1934 for plot 1A was 427.0 m<sup>3</sup> per dunum (10.25 m<sup>3</sup> per tree) and for plot 1B 410.4 m<sup>3</sup> per dunum (9.86 m<sup>3</sup> per tree). Owing to the lateness of the November rains, the original intention to give plot 1A three irrigations had to be abandoned. Plot 1B had its 4 irrigations as per programme — the last in 14th October. Plot 1A had its third and contemplated final irrigation on 13th and 17th September. The extra irrigation which was given on 14th November and as a winter irrigation is disregarded in the calculations.

There would appear to be every reason for optimism with regard to the future of the grove.

Further support is obtained for the claim that proof is already afforded of the unnecessarily high quantity of water used generally in the citrus area in Palestine, by the fact that during the soil moisture tests on the plots in Gan Moshe, receiving the lowest quantity of water, the moisture in the rooted areas of the soil was always above wilting point.

The question of reduction of water supply to a grove accustomed to large quantities, calls for careful consideration. If such is done at all it must be done by degrees. It must be remembered that the treatment of the Gan Moshe grove since its planting has been such as to encourage wide and deep rooting through furrow irrigation and reduced water supply. It is for this reason that details have been given of cultivation and soil treatment in addition to those of irrigation.

There is undoubtedly encouragement in the result of the investigation to growers, particularly in connection with new groves, to reduce the water supply. Such reduction of water duty and the extension of the irrigation interval is, in addition to its economic

aspect, to be appreciated still more as conducive to the health of the tree, providing as it does for a more widely spread root system and more complete aeration of the soil.

The advantages of furrow over basin irrigation have been emphasized in the body of the report.

The grove is open to inspection and it is the opinion of the conductors of the tests that its appearance at any time of the year is sufficient evidence that the reduction of water supply to it has been fully justified.

#### 11. CONTINUATION OF INVESTIGATIONS.

The investigations are being continued and promise to provide interesting information. It is intended to extend the intervals between irrigation to still longer periods than those used in 1933. A small part of plot 1A containing nine trees will not receive the final (3rd) irrigation of the season and the result of this somewhat drastic treatment will be closely observed.

Reference has been made in the report to the difficulty experienced in 1934 in plot 1A in maintaining the intention to view this plot as the Minimum Duty Plot, owing to the fact that the predetermined allowance is used up before the irrigation of the plot is completed. In the northern part of this plot it is found impossible to get the soil auger down to a metre depth. The reason for this will receive investigation. Moisture tests will be continued as far as funds and labour will permit, and in addition, an endeavour will be made to ascertain the most favourable moisture conditions for the tree.

---



APPENDIX TABLE No. I

COMPARISON OF WATER DUTY ON LIGHT SOIL IN DIFFERENT ORANGE (SHAMUTI) GROVES

| Location                        | Year<br>of<br>planting | Year<br>of<br>budding | No. of<br>trees<br>per dun. | Year<br>of<br>record | No. of<br>irrigations<br>per season | Quantity of water |                        | Method<br>of<br>irrigation | Remarks              |
|---------------------------------|------------------------|-----------------------|-----------------------------|----------------------|-------------------------------------|-------------------|------------------------|----------------------------|----------------------|
|                                 |                        |                       |                             |                      |                                     | per dun.          | per season<br>per tree |                            |                      |
| Gan Moshe                       | ...                    | 1930                  | 41.6                        | 1932                 | 5                                   | 493               | 11.9                   | basin                      | First fruit in 1933. |
|                                 |                        |                       |                             |                      | 4                                   | 390               | 9.4                    | furrow                     |                      |
|                                 |                        |                       |                             |                      | 3                                   | 313               | 7.5                    | furrow                     |                      |
|                                 |                        |                       |                             | 1933                 | 4                                   | 432               | 10.4                   | furrow                     |                      |
|                                 |                        |                       |                             |                      | 4                                   | 444               | 10.7                   | "                          |                      |
|                                 |                        |                       |                             |                      | 3                                   | 361               | 8.7                    | "                          |                      |
| Gan Rashal ...                  | ...                    | 1928                  | 40                          | 1932                 | 3                                   | 328               | 7.9                    | "                          | "                    |
|                                 |                        |                       |                             |                      | 5                                   | 550               | 13.7                   | furrow                     | First fruit in 1931. |
|                                 |                        |                       |                             |                      | 6                                   | 490               | 12.2                   | basin                      | "                    |
| Nes Tsivona, Mr. Löwenstein ... | 1928                   | 1928                  | 61.5                        | 1931                 | 9                                   | 1107              | 18.1                   | basin                      | First fruit in 1931. |
|                                 |                        |                       |                             | 1932                 | 9                                   | 732               | 11.9                   | "                          | "                    |
|                                 |                        |                       |                             | 1931                 | 8                                   | 980               | 18.2                   | "                          | "                    |
|                                 |                        |                       |                             | 1932                 | 7                                   | 650               | 12.0                   | "                          | "                    |
|                                 |                        |                       |                             | 1931                 | 9                                   | 815               | 13.0                   | "                          | "                    |
|                                 |                        |                       |                             | 1932                 | 8                                   | 737               | 11.8                   | "                          | "                    |
|                                 |                        |                       |                             | 1931                 | 7                                   | 636               | 12.9                   | "                          | "                    |
|                                 |                        |                       |                             | 1932                 | 7                                   | 611               | 12.4                   | "                          | "                    |
|                                 |                        |                       |                             | 1931                 | every 26-30 days                    | 581               | 12.6                   | basin                      | "                    |
| Magdiel ...                     | 1927                   | 1927                  | 46                          | 1931                 |                                     |                   |                        |                            |                      |

COMPARATIVE TABLE OF INVESTIGATIONS, 1A, 1B, 1A1, 2a, 2b, 2c, 2d, 2e, DURING THE YEARS 1931, 1932 AND 1933.

|                                                                                               | INVESTIGATION<br>No. 1 |       |       |       |       |       | INVESTIGATION<br>No. 2a/2d |       |       |       |       |       | INVESTIGATION<br>No. 2b |       |       |       |      |    | INVESTIGATION<br>No. 2c/2e |      |      |
|-----------------------------------------------------------------------------------------------|------------------------|-------|-------|-------|-------|-------|----------------------------|-------|-------|-------|-------|-------|-------------------------|-------|-------|-------|------|----|----------------------------|------|------|
|                                                                                               | 1931                   |       | 1932  |       | 1933  |       | 1931                       |       | 1932  |       | 1933  |       | 1931                    |       | 1932  |       | 1933 |    | 1931                       | 1932 | 1933 |
|                                                                                               | A                      | B     | A     | B     | A     | B     | A1                         | 2a    | 2a    | 2d    | 2b    | 2b    | 2b                      | 2b    | 2c    | 2c    | 2e   | 2e | 2e                         | 2e   | 2e   |
| 1. Period during which irrigation took place from first irrigation to first rainfall—in days. | 162                    | 161   | 126   | 127   | 138   | 144   | 138                        | 163   | 154   | 141   | 159   | 168   | 154                     | 156   | 171   | 155   |      |    |                            |      |      |
| 2. Number of irrigations                                                                      | 3                      | 3     | 3     | 4     | 3     | 4     | 3                          | 4     | 5     | 4     | 4     | 5     | 5                       | 4     | 6     | 6     |      |    |                            |      |      |
| 3a. Total Q. per dun. in m <sup>3</sup>                                                       | 260.7                  | 268.5 | 313.3 | 390.2 | 360.9 | 443.8 | 328.1                      | 251.6 | 493.3 | 432.2 | 176.4 | 350.5 | 380.7                   | 209.3 | 439.4 | 482.0 |      |    |                            |      |      |
| 3b. Total Q. per tree in m <sup>3</sup>                                                       | 6.27                   | 6.45  | 7.53  | 9.38  | 8.67  | 10.67 | 7.87                       | 6.05  | 11.86 | 10.38 | 4.25  | 8.48  | 9.18                    | 5.02  | 10.54 | 11.56 |      |    |                            |      |      |
| 4a. Average Q. per dun. for one irrigation in m <sup>3</sup>                                  | 86.9                   | 89.5  | 104.3 | 97.6  | 120.3 | 110.9 | —                          | 62.9  | 98.7  | 108.0 | 44.1  | 70.1  | 76.1                    | 52.4  | 72.3  | 80.3  |      |    |                            |      |      |
| 4b. Average Q. per tree for one irrigation in m <sup>3</sup>                                  | 2.09                   | 2.15  | 2.51  | 2.34  | 2.88  | 2.67  | —                          | 1.51  | 2.37  | 2.59  | 1.06  | 1.69  | 1.83                    | 1.26  | 1.76  | 1.93  |      |    |                            |      |      |
| 5. Average interval between irrigations—in days.                                              | 44                     | 39.5  | 45    | 35    | 44    | 36.3  | 44                         | 42.3  | 32.0  | 35.7  | 38.7  | 33.8  | 34.2                    | 39.0  | 35.2  | 29.4  |      |    |                            |      |      |
| 6a. Average Q. per dunum per day 4a ÷ 5 in meters cube.                                       | 1.97                   | 2.27  | 2.23  | 2.79  | 2.74  | 3.06  | —                          | 1.48  | 3.08  | 3.03  | 1.14  | 2.07  | 2.22                    | 1.34  | 2.08  | 2.73  |      |    |                            |      |      |
| 6b. Average Q. per tree per day 4b ÷ 5 in meters cube.                                        | .047                   | .055  | .056  | .067  | .066  | .074  | —                          | .036  | .074  | .073  | .027  | .050  | .053                    | .032  | .050  | .066  |      |    |                            |      |      |
| 7a. Average Q. per dunum per day over whole irrigation period 3a ÷ 1                          | 1.61                   | 1.67  | 2.49  | 3.07  | 2.61  | 3.06  | —                          | 1.54  | 3.20  | 3.06  | 1.11  | 2.08  | 2.47                    | 1.34  | 2.57  | 3.11  |      |    |                            |      |      |
| 7b. Average Q. per tree per day over whole irrigation period 3b ÷ 1                           | .039                   | .040  | .060  | .074  | .063  | .074  | —                          | .037  | .077  | .074  | .027  | .050  | .059                    | .032  | .062  | .075  |      |    |                            |      |      |

NOTE: In the above table winter irrigations are not included.



## RESULTS OF ANALYSIS ON EIGHT SAMPLES OF SOIL SUBMITTED BY THE DEPARTMENT OF DEVELOPMENT

SOURCE :- FROM GAN MOSHE NEAR RISHON LE TSIYON.

| MECHANICAL ANALYSIS. |          |               |             |               | PHYSICAL DETERMINATIONS. |              |                  |              | CHEMICAL ANALYSIS.                                    |                                        |                      |                   |                    |
|----------------------|----------|---------------|-------------|---------------|--------------------------|--------------|------------------|--------------|-------------------------------------------------------|----------------------------------------|----------------------|-------------------|--------------------|
| Sample No.           | Depth m. | Coarse sand % | Fine sand % | Silt & Clay % | Water-Holding capacity % | True Sp. Gr. | Apparent Sp. Gr. | Pore Space % | (Na <sub>2</sub> CO <sub>3</sub> ) Black Alkalinity % | WATER EXTRACT, 1 : 5 White Alkalinity. |                      |                   | Total Alkalinity % |
|                      |          |               |             |               |                          |              |                  |              |                                                       | Ca (HCO <sub>3</sub> ) <sub>2</sub> %  | NaHCO <sub>3</sub> % | SO <sub>4</sub> % |                    |
| 1a                   | 1.20     | 54.4          | 17.4        | 28.2          | 49.1                     | 2.51         | 1.37             | 45.4         | NIL                                                   | 0.010                                  | 0.007                | Traces            | 0.017              |
| 1b                   | 0.60     | 64.4          | 17.0        | 18.6          | 43.4                     | 2.53         | 1.38             | 45.4         | NIL                                                   | 0.010                                  | 0.005                | Traces            | 0.015              |
| 1c                   | 0.20     | 58.4          | 16.0        | 25.6          | 47.8                     | 2.51         | 1.38             | 45.0         | NIL                                                   | 0.009                                  | 0.005                | Traces            | 0.014              |
| 2a                   | 1.10     | 38.0          | 17.8        | 44.2          | 53.5                     | 2.45         | 1.36             | 44.5         | NIL                                                   | 0.016                                  | 0.010                | Traces            | 0.026              |
| 2b                   | 0.20     | 65.4          | 18.4        | 16.2          | 40.8                     | 2.58         | 1.46             | 43.4         | NIL                                                   | 0.016                                  | 0.007                | Traces            | 0.023              |
| 3a                   | 1.10     | 62.2          | 15.6        | 22.2          | 48.8                     | 2.52         | 1.38             | 45.2         | NIL                                                   | 0.014                                  | 0.007                | Traces            | 0.021              |
| 3b                   | 0.50     | 75.8          | 16.6        | 7.6           | 44.9                     | 2.58         | 1.48             | 42.6         | NIL                                                   | 0.010                                  | 0.007                | Traces            | 0.017              |
| 3c                   | 0.20     | 75.6          | 17.8        | 6.6           | 31.6                     | 2.60         | 1.50             | 42.3         | NIL                                                   | 0.010                                  | 0.005                | Traces            | 0.015              |

1. The Sudan-Sedimentation Method for Mechanical Analysis has been used.

2. Pore space =  $\frac{A-B}{A} \times 100$ .

Where A = True Specific gravity

B = Apparent Specific gravity.

It will be seen from the above data that these are light sandy soils rather low in phosphates, organic matter and total nitrogen and that the last two samples have the lowest lime content.

Sgd: G. W. BAKER  
Government Analyst

4.1.34

CL/9/5(5721)

P. T. O.

Page 2. (continued)

| Sample No. | Depth m. | Total solids at 105° C. | Chlorine (Cl) % | HCL — EXTRACT                   |                    |                              | Humus (Grandeau) % | Total Nitrogen |
|------------|----------|-------------------------|-----------------|---------------------------------|--------------------|------------------------------|--------------------|----------------|
|            |          |                         |                 | P <sub>2</sub> O <sub>5</sub> % | K <sub>2</sub> O % | CaCO <sub>3</sub> from CaO % |                    |                |
| 1a         | 1.20     | 0.25                    | 0.002           | 0.008                           | 0.347              | 0.429                        | 0.09               | 0.017          |
| 1b         | 0.60     | 0.20                    | 0.002           | 0.009                           | 0.306              | 0.300                        | 0.09               | 0.014          |
| 1c         | 0.20     | 0.20                    | 0.004           | 0.007                           | 0.313              | 0.314                        | 0.06               | 0.014          |
| 2a         | 1.10     | 0.19                    | 0.005           | 0.012                           | 0.401              | 2.315                        | 0.20               | 0.022          |
| 2b         | 0.20     | 0.21                    | 0.002           | 0.0128                          | 0.340              | 0.830                        | 0.21               | 0.031          |
| 3a         | 1.10     | 0.19                    | 0.002           | 0.010                           | 0.408              | 0.300                        | 0.12               | 0.020          |
| 3b         | 0.50     | 0.18                    | 0.004           | 0.005                           | 0.524              | 0.093                        | 0.05               | 0.014          |
| 3c         | 0.20     | 0.17                    | 0.002           | 0.005                           | 0.496              | 0.107                        | 0.11               | 0.017          |







